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The Effect of Wrapping Material on Freezing Rate, Quality and Cooking Losses of Beef Frozen and Stored in Home Freezer Units

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THE EFFECT OF WRAPPING MATERIAL ON FREEZING RATE, QUALITY AND COOKING LOSSES OF BEEF FROZEN AND STORED IN HOME FREEZER UNITS

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This is to certify that, in accordance with the requirements of South Dakota State College for the Master of Science Degree, Mr. Robert Dynes has presented to this committee three bound copies of an acceptable thesis, done in the major field; and has satisfactorily passed a two-hour oral examination on the thesis, the major field, Animal Husbandry, and the minor field, Zoology.

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TABLE OF CONTENTS

List of Tables

List of Figures

INTRODUCTION

Meat is an essential food in the daily menu of growing and working Americans. Due to meat production methods and population distribution, this meat must often be preserved for a considerable length of time. If better and more accessible storage methods and facilities were readily available, more meat could be used to great advantage in the diets of all people. It is for these reasons that constant effort is being put forth to find better and more efficient means for its preservation.

Freezing as a method of preservation for perishable food products has been used for many years. Artifical freezing of meat was discovered accidentally about 1880, when a refrigerated shipment of meat from Australia to England became frozen enroute. Since that time many improvements have been made in the methods of refrigeration. The increased popularity of freezing meat led to the development of the frozen food locker system which was inaugurated in 1908. Home freezers are the latest innovation for food preservation. These have increased in popularity and present estimates are that about 1,400,000 units are being used in American homes today.

The most recent influx of home freezer units has created a demand for additional knowledge which will increase their efficiency. One of the most common questions asked is, "What wrapping materials should I use when freezing and storing meat in home freezer units?" The answer to this question can be found only by testing wrapping materials on meat frozen and stored in home freezers.

To date most research on home units has dealt with such factors as economy and operation of freezer cabinets. Donnalley (1944) and Masterman (1943) have conducted some controlled studies on these phases. The work done in comparing different wraps in locker plants has shown that they do have an effect upon the freezing rate, shrinkage, and the quality of frozen meats. The laws of physics tell us that temperature fluctuations are much more rapid in small areas than in large areas. Finnegan (1939) has shown that temperature fluctuations affect the quality of stored meats; therefore, it seems probable that wrapping materials which are suitable for use in locker plants may not serve satisfactorily in home freezer units.

Any information available will have real commercial value. With the number of home freezers now in use consumers are storing large quantities of food, of which approximately eighty-five per cent is meat.

REVIEW OF LITERATURE

Voluminous literature is available on the freezing and storage of beef and other meats in locker plants. In general, this research has shown that the quality of beef or other meat is not improved by freezing but can be maintained for relatively long periods of time if properly frozen and stored. B. A. I. Personnel (1939) (1940), Bray, et al, (1941), Brady, et al, (1942), Miner, et al, (1945), Kunkle (1943), Mackintosh (1943) (1949) have all agreed on these essential facts.

Freezer burn and rancidity are the most common causes of low quality in stored frozen meat. Finnegan (1939) reported that dehydration of frozen food is caused by two factors, first, the temperature difference between the air and the refrigerant and second, fluctuating air temperatures. These factors effect the stability of the relative humidity in the freezing compartment. The maintenance of a high relative humidity will reduce the degree of dehydration. Miner, et al, (1948) showed that desiccation of frozen meat was retarded by high fat content and low storage temperatures. Winter and workers (1949) report that freezer burn may or may not be accompanied by rancidity.

Rancidity in meat is most commonly caused by exposure of the natural fats and oils to atmospheric oxygen. Mackintosh (1949) related that during the development of freezing as a method of preservation, meat was often frozen without any wrapping material with the result that freezer burn developed early in storage and was usually accompanied by rancidity.

:cording to Winter (1949) a good wrapping material will protect the roduct from evaporation and prevent the development of rancidity by xclusion of oxygen.

Wrapping materials should be moisture-vapor proof to prevent loss f moisture. Dubois and Tressler (1939) have found that a wrapping ma- erial is satisfactory for use in packaging foods for storage in lockers, f at 5° F. it transmits not more than three grams of moisture-vapor er square meter per twenty-four hours. In addition, the material hould not be stained by blood or grease which would cause the paper o adhere to the frozen meat. Neither should it become brittle at low emperatures or impart a flavor to the food.

A wrapping material may be moisture-vapor proof but not pliable nough to conform to the shape of the product. As a result, dehydra- ion takes place in crevices and air pockets. Christensen (1945) emonstrated this with a frozen apple sealed in a standard moisture- apor proof package and stored in a freezer subjected to frequent tem- erature changes. Although the package did not lose weight, the apple ehydrated. Sayles, et al, (1946) have also shown that completely oisture-vapor proof wraps will prevent a loss of weight from the pack- ge but will not protect food from moisture loss within the wraps if arge cavities exist. This internal drying is evidenced by a heavy eposit of frost called "cavity ice" on the inner surface of the vapor arrier and around the food particles.

Kunkle (1943), Mackintosh (1943) (1949), and Winter, et al, (1949) ist other requirements of good freezer wrap materials. These include igh wet strength, absence of odor when damp, tastelessness, resistance

to outside odors, and pliability at low temperatures. It should also have good stripping qualities, resistance to tears and punctures, and an external surface suitable for marking.

Ordinary butcher paper was one of the first materials used in wrapping meat for freezing. Although it was usually water proof it was not moisture-vapor proof and meats so wrapped became freezer burned and rancid. Extensive search has been made to find wrapping materials that will keep meat in good condition. Cellophane was one of the first satisfactory wraps to meet most of the requirements for storage. Dubois and Tressler (1939) tested several types of cellophane which have been developed and found them very satisfactory. Winter (1949) and Mackintosh (1949) recommended three types of cellophane for moist foods. These are Dupont's M.S.A.T. 83 or 87 and Sylvania's M.S.B.F.-3.

Tressler and Evers (1947) describe packaging materials which conform to the shape of the product. These include Goodyear Pliofilm, Marathon's Parakote, and Betner's Lamofilm. They also described an excellent wrapping material in the form of a latex rubber bag known as Cry-O-Vac developed by the Dewey and Almy Chemical Co. Winter (1949) and Mackintosh (1949) suggested films other than pliofilm and cellophane such as polyethylene and vinyl derivatives which are available in sheet or bag form. They also suggest laminated glassine paper, laminated aluminum foil, aluminum foil, and laminated wax and cellophane papers. The Wax Dip or No Air Wrap is also an excellent covering material. These same workers also stated that the added protection offered by this group of wrapping materials more than offsets any

additional cost.

Wax papers commonly used by the freezer locker trade have not been found highly satisfactory in preventing desiccation and rancidity development. Tressler and Evers (1947) showed that some wax papers tested for moisture-vapor transmission had an average loss in grams per square meter per day ranging from 5.71 to 8.47. Some of the moisture proof, transparent, viscose sheets had a moisture-vapor loss range from 0.17 to 0.27. Winter (1949) suggested that if wax papers are used, a double thickness should be made with the wax side next to the meat. Mackintosh (1949) stated that wax papers should not be used on meat if it is to be stored over three or four months.

B. A. I. Personnel (1943) tested lard as a substitute for moisture-vapor proof wrappings. Weight loss was 21.7 per cent in frozen pork loins coated with lard and stored at 18° F. for thirty-six weeks. Practically no loss was observed in other samples similarly protected but stored at 0° F. Hiner and Kauffman (1944) tested lard, beef tallow, and combinations of both, as wrapping materials and concluded that meats may be frozen, dipped in melted lard at 100° to 200° F., and stored at 0° F. for sixty-four weeks with very satisfactory results. Ziegler, et al, (1948) reported that round steaks which were coated with lard without wraps became rancid and "fishy" in taste after six months storage. Comparable lard dipped steaks which were wrapped in cellophane had a somewhat better flavor but were still of such poor quality that the practice was not recommended. Similar steaks dipped in ice water twice and stored for six months retained good quality, especially when wrapped in cellophane. Iced steaks which were not wrapped in cellophane had to be

re-iced at the end of three months. A report by Miner, et al, (1948) showed that cellophane and lard coatings were satisfactory protectants against desiccation. Deterioration at temperatures from 18° to 0° F. was primarily due to oxidation of the fat resulting in a progressive decrease in the desirability of its flavor. These same workers also stated that vacuum packing at a pressure of twenty-eight inches of mercury was the most efficient and possibly the most economical method of increasing storage life.

Two methods of wrapping meat for freezing are in general use at the present time. These are the drug-store or confectioner's wrap and the butcher's wrap. To prevent air pockets and get a tight wrap, Masterman and Winsor (1946) suggest the drug-store wrap and highly recommend it for meat cuts that are to be kept flat, as steaks and chops. They further state, however, that the butcher style may be more efficient than the druggist style, particularly where wrapping material of low quality is used. Mackintosh (1949) also favors the drug-store wrap but states that the butcher's wrap is equally as good if properly applied. Either method if done haphazardly or carelessly will result in improper protection and under such conditions the best wrapping material available has little advantage over inferior materials. Winter (1949) states that about twenty per cent less paper is required to wrap one hundred pounds of meat by the drug-store method.

Investigations at the University of Minnesota conducted by Winter, et al, (1949) have shown that there is little difference in the quality of meats cooked before or after thawing. According to Fenton (1943) frozen meat requires a cooking time of fifteen to twenty-five minutes

more per pound. Child and Paul (1937) found that roasts thawed more quickly at 75° C. but had a higher total loss in drip and press fluids than similar roasts thawed at 24° to 25° C. The palatability of the meat was unaffected by thawing temperatures. These same workers also found that total moisture and drip loss, as well as tenderness of the cooked beef, was unaffected by thawing temperature.

Brady, et al, (1942) suggests that thin cuts of meat such as steaks and chops should be cooked before thawing. It was also found that steak which was broiled when frozen had the least cooking loss and no apparent loss in palatability. Fenton (1943) reports that steaks of 1½ inches or more in thickness should be partially or completely thawed before cooking. This procedure is also recommended by Groppe (1943) in order to have a more uniform product after cooking. Vail (1949) suggests thawing in a refrigerator as a method of reducing leakage or drip.

Vail, et al, (1943) thawed frozen steak at room temperature for fifteen hours, at a refrigerator temperature of 38° F. for twenty-five hours, and at an oven temperature of 350° F. The steaks thawed at oven temperatures were slightly less tender and required a longer cooking time than the others. The steaks thawed at room temperature had the highest per cent of drip loss and press fluids.

B. A. I. Personnel (1940), Dubois, et al, (1940), Cook and White (1941), and Shrewsbury, et al, (1945) have found 0° F. or lower to be the most desirable temperature for storing frozen beef. Results of studies conducted by Filinger and Mackintosh (1943) and Mackintosh (1949) indicated that frozen beef can be stored satisfactorily at 0° F. for a period of nine to twelve months. This is in agreement with

storage time recommended by Kunkle (1943). Winter and Hustrulid (1945) reported that storage periods of twelve to fifteen months at 0° F. were satisfactory but in later studies these same workers (1949) reduced this period to eight to twelve months.

Drip or moisture loss of meat during thawing is definitely affected by freezing rate. Ramsbottom and Koonzs (1940) reported that drip loss was significantly affected by temperature of freezing and length of time in storage but storage temperature did not affect it. Investigations by Hiner, et al, (1945) showed that drip was decreased as freezing temperatures were lowered from 18 to -114° F. They postulated that drip was reduced because the increased intra-fibrillar freezing and rupturing of the fibers permitted the proteins to reabsorb a large portion of the water originally frozen in the meat. Tressler and Evers (1947) report that slow freezing results in the formation of a small number of large ice crystals; and rapid freezing results in a large number of small ice crystals. These workers also report that other factors influence the amount of drip in thawing; however, these factors remaining the same, results show less drip from rapidly frozen meat. Sair and Cook (1938) and Ramsbottom and Koonz (1940) reported that drip loss is reduced as the period of time between slaughtering and freezing is lengthened.

METHODS AND MATERIALS

This study involves the comparative efficiency of wrapping materials in home freezer units and commercial locker plants. It was conducted in the South Dakota State College Meat Laboratory and the Brookings Community Locker Plant (hereafter designated as "locker plant"). The cooking tests were conducted in the South Dakota State College Home Economics Department. All tests were completed during the period of February 28, 1948 to May 28, 1949. Beef was the only meat studied.

The home freezer units used in this experiment are shown in Figure 1. They were (1) Hot Point Freezer, 8 cubic foot capacity of the deep-chest type with a sealed unit type of construction, (2) Gibson Home Freezer, 6½ cubic foot capacity of the vertical cabinet type with sealed unit construction and (3) American Home Freezer, 8 cubic foot capacity of the deep-chest type with a separate compartment for sharp freezing and open-type unit construction.

Three separate freezing periods were conducted on beef roasts, loin steaks, round steaks and ground beef. Prior to cutting, the beef was aged for seven days at a storage temperature of 36° to 38° F. The roasts were cut from the wholesale rib and chuck. All rib roasts were prepared by removing the short-rib section and a portion of the chine bone. The chuck pot roasts were cut from both the arm and blade sections with approximately two inches of thickness. The sharp edges of bone were removed from all blade roasts to prevent the wrapping materials from being torn. All round steaks were cut five-eighths of an inch in thickness and were divided and arranged to facilitate

compact wrapping. The loin steaks were cut from the wholesale loin and two steaks were placed in each package. The ground beef was made from lean trimmings by processing it through a half-inch and eighth-inch chopping plate. All beef was purchased from commercial packing companies and graded average good according to the United States Department of Agriculture standards.

Wrapping materials used included (1) a petroleum wax known by the trade name of "No Air Wrap", (2) a wax locker paper, waxed on one side only, (3) a laminated aluminum foil and (4) a laminated wax paper. All of the preceding materials are commercially manufactured and available to the freezer locker trade. The Standard confectioners or drug-store style wrap as described and illustrated by Gortner, et al, (1948), Mackintosh (1949) and Winter, et al, (1949) was used where the meat was wrapped in the paper material. A dip-tank was employed for applying the petroleum wax after the meat had been frozen.

Sixteen cuts were randomly allocated in such a manner that four cuts of each type were wrapped in different materials and placed in each freezing unit. The roasts were cut to an average weight of 1,590 grams, round and loin steak 1,035 and 1,002 grams respectively, and ground beef 683 grams per package. The cuts were wrapped immediately after cutting in the wrapping materials being tested, with the exception of those given the "No Air Wrap". These cuts were dipped in the petroleum wax substance the morning after freezing.

The home freezers were run a period of twelve hours, at their lowest temperature setting, prior to each freezing test. During the first freezing test all the home freezers were empty, whereas the two

succeeding tests were made with the previously frozen meat in storage. No precautions were taken to provide maximum freezing capacity at the locker plant and all freezing was done under normal operating condition.

Temperature readings were made by the use of a potentiometer indicator and thermocouple wires, Figure 1. Thermocouple wires were inserted into the center of the meat cut. After placing the packages in the freezer, the thermocouple wires were passed under the door to a rotary switch connected to a Leeds and Northrup Potentiometer Indicator as shown in Figure 2. All temperatures were recorded every fifteen minutes except in period two when home freezer temperatures were taken at twenty minute intervals. Readings were recorded until all packages had reached 0° F. Immediately after freezing the wires were cut close to the package and the opening was sealed.

After the meat had been in storage from five to ten months, it was taken from the freezers. The wrapping material was removed and the cuts weighed to determine loss in weight during freezing and storage. The ground beef was thawed at room temperature for a period of five hours and all other was thawed for a twelve hour period. Following thawing all cuts were weighed to determine drip loss.

Immediately after the thawing period, each package of ground beef was made into five one-hundred-gram patties, of approximately the same thickness. These were placed on a broiler rack two inches from the source of heat and broiled four minutes on each side. All patties were weighed together to determine loss in weight of the cooked sample. The standing rib roasts were placed on a rack in a shallow pan and roasted at 300° F. The pot roasts were braised without

previous searing. All roasts were cooked until the internal temperature reached 170° F. Representative samples of round steak were taken from each package and cooked by braising without previous searing. One loin steak was taken from each package and weighed. It was placed on a broiler rack two and one-half to three inches below the source of heat and broiled eight minutes on each side. Each roast, round steak and loin steak sample was weighed separately to determine loss in weight during cooking.

Freezing zone data were measured from large scale graphs according to the method described by Donnalley (1944). Freezing rates were calculated by dividing the temperature of the meat at the start of the freezing period by the number of minutes required for it to reach 0° F. This method gives an average freezing rate in degrees drop per minute. Percentage losses in weight were calculated on all cuts of meat during freezing, storage, and cooking. Statistical treatment, analysis of variance, was applied to all data (Snedecor, 1946).

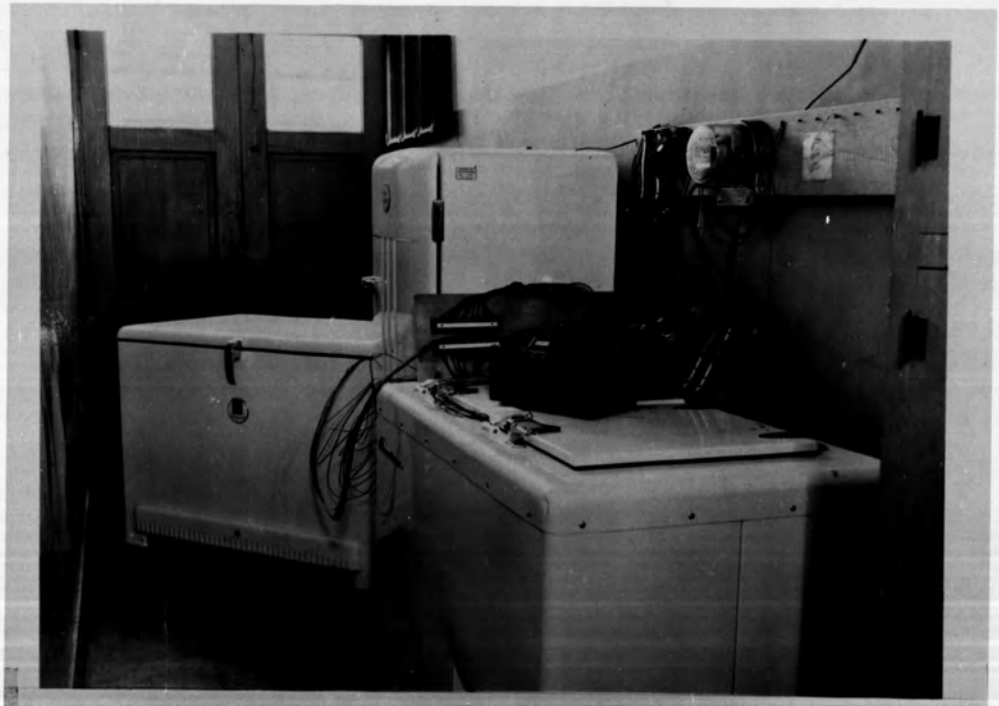

Figure 1. Home freezer units and temperature determining apparatus used in this study.

Figure 2. Leeds and Northrup Potentiometer Indicator used to determine temperatures during the freezing periods.

ANALYSIS OF DATA AND RESULTS

This study was designed to compare the efficiency of various types of wrapping materials on frozen and stored beef. A comparison of freezing units was also made since the data were available on the three types used. The results of the latter comparison are not conclusive because sufficient numbers of each type of machine were not available.

Mean Weight and Freezing Rate of Meat Cuts

Table 1 includes the mean weight in grams of roasts, round and loin steaks, and ground beef wrapped in the various materials. Table 2 includes the weight in grams of roasts, round and loin steaks, and ground beef frozen and stored in the various freezing units.

Table 1.

MEAN WEIGHT IN GRAMS OF CUTS FROZEN IN WRAPPING MATERIALS STUDIED

	Meat Cuts			
Wrapping Materials	Roasts	Round Steak	Loin Steak	Ground Beef
No Air Wrap	1590	1040	1004	684
Wax Paper	1566	1042	994	684
Laminated Aluminum Foil	1562	1032	1002	684
Laminated Wax Paper	1540	1029	1010	684

It may be noted in these tables that the means of the same type of cut varied more between freezing units than between the different wrapping materials. The only exception was the ground beef which had quite similar means in both instances. All weights were analyzed statistically to

determine the differences between wrapping materials and freezing units. The results of this analysis are shown in Table 3.

Table 2.

MEAN WEIGHT IN GRAMS OF MEAT CUTS FROZEN IN ALL FREEZER UNITS

	Meat Cuts			
Freezing Unit	Roasts	Round Steaks	Loin Steaks	Ground Beef
Locker Plant	1661	994	1044	687
Hot Point	1534	1051	988	683
Gibson	1528	1039	988	683
American	1535	1058	990	684

Table 3.

MEAN SQUARES OF VARIANCE OF WEIGHTS OF THE MEAT CUTS STUDIED

		Meat Cuts			
Source of Variance	d/f	Roasts	Round Steaks	Loin Steaks	Ground Beef
Total	47				
Between Wraps	3	5,075	450	566	0.66
Between Lockers	3	49,890**	9,943*	9,525**	40.66**
Wraps X Lockers	9	3,358	1,924	1,053	0.88
Between Periods	2	43,658**	82,122**	425,482**	512.00**
Wraps X Periods	6	2,557	2,447	1,017	1.66**
Lockers X Periods	6	36,834**	1,418	25,506**	98.66**
Error	18	3,492	1,362	1,118	0.61

* Indicates significance at the 5% level
** Indicates significance at the 1% level

In this study an asterisk (*) or the word "significant" has been used to indicate that such a value could occur by chance in not more than

five or less than one per cent of similar trials. A double asterisk (**) or the words "highly significant" have been used to indicate a value that may occur by chance in one per cent or less of similar trials.

It may be noted in Table 3 that there is no significant difference in the weights of the cuts wrapped in the different wrapping materials. Thus it appears that any differences found in the study are likely to be the results of the wrappings and not the size of the cuts being compared. The significant difference between lockers and periods in the weight of cuts stored indicate that little faith can be placed in the differences found between storage units.

Freezing Zone and Rate Analysis

Freezing zone data for all cuts, freezing units and wrapping materials used in this study are presented in Tables 4 and 5. Table 4 shows the effects of wrapping materials on the mean freezing zone of different meat cuts. It is clearly shown in this table that less time is required for meat to pass through the freezing zone when the "No Air Wrap" method is used. With round steaks, loin steaks, and ground beef, the period of time required was only approximately half of that required for the same cuts wrapped in the other materials. Only small differences were present between the mean freezing zone of the three paper wraps.

The means of the freezing zone time for cuts frozen in the various units are shown in Table 5. The American freezer had a much shorter freezing zone for all cuts than any of the other units. It is also interesting to note that all home units had a shorter freezing zone time than the commercial locker plant. Further observation reveals that

differences between means for freezing units are not as great as the differences in means for wrapping materials.

Table 4.

MEAN FREEZING ZONE IN MINUTES FOR ALL WRAPPING MATERIALS

	Wrapping Materials				
Meat Cut	No Air Wrap	Wax Paper	Laminated Aluminum Foil	Laminated Wax Paper	All Materials
Roasts	203	329	344	341	304
Round Steak	137	312	333	315	274
Loin Steak	124	282	270	285	240
Ground Beef	155	313	262	291	255
All Cuts	155	309	302	308	

Table 5.

MEAN FREEZING ZONE IN MINUTES FOR ALL FREEZING UNITS

	Freezing Unit				
Meat Cut	Locker Plant	Hot Point	Gibson	American	All Freezers
Roasts	394	330	262	229	304
Round Steak	347	290	232	226	274
Loin Steak	280	272	213	196	240
Ground Beef	294	251	268	209	256
All Cuts	329	286	244	215	

The analysis of variance of freezing zone time is shown in Table 6. That wrapping materials have a very definite effect on the length of freezing time is clearly shown by the highly significant differences between wrapping materials. These differences, which were present in all cuts of meat, are largely due to the short freezing zone of the "No Air Wrap" as shown in Table 4.

Table 6.

MEAN SQUARES OF VARIANCE OF FREEZING ZONE TIME IN MINUTES

Source of Variance	d/f	Meat Cuts			
		Roasts	Round Steak	Loin Steak	Ground Beef
Total	47				
Between Wraps	3	55,359**	101,703**	72,777**	59,040**
Between Lockers	3	64,769**	38,319**	21,102*	15,338*
Wraps X Lockers	9	5,289	2,828	3,232	2,431
Between Periods	2	3,942	29,172*	12,604*	6,403
Wraps X Periods	6	4,696	1,600	3,779	4,220
Lockers X Periods	6	5,082	11,344	2,257	6,166*
Error	18	3,934	5,037	2,123	1,980

* Significant at the 5% level
** Significant at the 1% level

It is further indicated in Table 6 that real differences between freezing units do exist. This is portrayed by the highly significant differences in freezing zone between lockers in the case of roasts and round steak and the significant differences between loin steak and ground beef. The variations between periods are probably associated with the weight differences shown in Table 3.

The mean freezing rates for wrapping materials and freezer units are presented in Tables 7 and 8. These data represent drop in degrees Fahrenheit per minute. Table 7 shows that meat freezes in less time when wrapped by the "No Air Wrap" method and that there are only slight variations in freezing rates among the other wrapping materials. A direct relationship appears to exist between size of cut and freezing rate. This is shown by the fact that the small ground beef packages consistently froze

at a more rapid rate than did any of the larger cuts. The roasts had the slowest freezing rate of all cuts and were also the largest. It would seem, therefore, that size and thickness of package has an effect on freezing rate as well as on the length of freezing zone as shown in Table 4.

Table 7.

MEAN FREEZING RATE FOR ALL WRAPPING MATERIALS

	Wrapping Materials				
Meat Cut	No Air Wrap	Wax Paper	Laminated Aluminum Foil	Laminated Wax Paper	All Materials
Roasts	.1123*	.0668	.0716	.0694	.0800
Round Steak	.1492	.0818	.0812	.0815	.0984
Loin Steak	.1460	.0811	.0897	.0808	.0994
Ground Beef	.1320	.0880	.0949	.0864	.1003
All Cuts	.1348	.0794	.0844	.0795	

* Represents drop in degrees Fahrenheit per minute.

Table 8.

MEAN FREEZING RATE FOR ALL FREEZING UNITS

	Freezing Units				
Meat Cut	Locker Plant	Hot Point	Gibson	American	All Freezers
Roasts	.0638*	.0728	.0876	.0958	.0800
Round Steaks	.0754	.0866	.1136	.1192	.0984
Loin Steaks	.0794	.0896	.1010	.1275	.0994
Ground Beef	.0942	.0974	.0942	.1156	.1003
All Cuts	.0782	.0866	.0988	.1145	

* Represents drop in degrees Fahrenheit per minute.

The mean freezing rates of the various cuts as effected by freezing units are shown in Table 8. Observation of this table confirms the freezing zone data of Table 5. in that all home freezer units had more rapid freezing rates than the locker plant.

The mean squares of variance of freezing rate which are presented in Table 9 substantiate the conclusion made from studying Table 6.

Table 9.

MEAN SQUARES OF VARIANCE OF FREEZING RATE IN DEGREES DROP PER MINUTE

		Meat Cut			
Source of Variance	d/f	Roasts	Round Steak	Loin Steak	Ground Beef
Total	47				
Between Wraps	3	0.0056**	0.0138**	0.0118**	0.0055**
Between Lockers	3	0.0025*	0.0052*	0.0051*	0.0012*
Wraps X Lockers	9	0.0004	0.0012	0.0008	0.0002
Between Periods	2	0.0002	0.0034**	0.0007	0.0000
Wraps X Periods	6	0.0002	0.0005	0.0006	0.0002
Lockers X Periods	6	0.0004	0.0008*	0.0002	0.0004
Error	18	0.0003	0.0002	0.0002	0.0002

** Significant at the 1% level
* Significant at the 5% level

Effect of Freezing and Storage

Percentage weight losses were calculated on all meat cuts. This procedure eliminated the effect of weight differences as shown in Table 3 and allowed for the statistical analysis of the variations found between lockers.

The mean percentage losses in weight due to wrapping materials are tabulated in Table 10.

Table 10.

MEAN WEIGHT LOSSES DURING FREEZING AND STORAGE DUE TO WRAPPING MATERIALS

	Wrapping Material				
Meat Cut	No Air Wrap	Wax Paper	Laminated Aluminum Foil	Laminated Wax Paper	All Materials
Roasts	1.42*	5.08	0.39	1.05	1.98
Round Steaks	2.97	6.93	1.33	2.63	3.46
Loin Steaks	2.62	5.70	0.85	1.63	2.70
Ground Beef	2.17	4.95	0.47	1.21	2.20
All Cuts	2.30	5.66	0.76	1.63	

* Represents percentage weight loss of all cuts.

It may be observed from the above table that large variations exist between wrapping materials. This fact is especially true for the roasts with weight losses ranging from 0.39 to 5.08 per cent. The round steak had an even wider range in percentage weight loss, which was 1.33 per cent for the laminated aluminum foil wrapping material as compared to 6.93 per cent for the wax paper. Similar variations in percentage weight losses are present in the other cuts studied. The largest weight loss always occurred when the cuts were wrapped in the wax paper. This fact might well be attributed to the high moisture-vapor transmission of the wax paper when only one thickness is applied to the meat. In contrast to the wax paper, the cuts wrapped in the laminated aluminum foil had comparatively small losses in weight. This is due to the greater resistance to moisture-vapor transmission of the foil material.

It is interesting to note that mean percentage weight losses for the "No Air Wrap" are very similar to the average percentage weight losses for all wrapping materials.

The percentage weight losses of the various cuts for the freezing units are presented in Table 11.

Table 11.

MEAN WEIGHT LOSSES DURING FREEZING AND STORAGE DUE TO FREEZING UNITS

	Freezing Unit				
Meat Cut	Locker Plant	Hot Point	Gibson	American	All Units
Roasts	1.49*	1.94	2.14	2.37	1.98
Round Steak	1.93	4.04	3.11	4.78	3.46
Loin Steak	2.20	2.93	2.83	2.84	2.70
Ground Beef	1.67	2.00	2.70	2.44	2.20
All Cuts	1.82	2.73	2.70	3.11	

* Represents per cent loss in weight of all cuts.

It will be noted in the above table that there are only slight variations in weight losses during freezing and storage in the different freezing units. The weight losses in the locker plant were less than those found in the other freezing units. The larger weight losses in the home freezers are probably due to fluctuating temperatures which are much more prevalent in the home units than in the locker plant and to the low humidity of the home freezers as contrasted to the relatively high humidity of the locker plant.

Table 12.

MEAN SQUARES OF VARIANCE OF PERCENTAGE WEIGHT LOSSES DUE TO WRAPS AND FREEZERS

		Meat Cut			
Source of Variance	d/f	Roasts	Round Steak	Loin Steak	Ground Beef
Total	47				
Between Wraps	3	.0053**	.0070**	.0054**	.0046**
Between Lockers	3	.0002	.0018**	.0001	.0003
Wraps X Lockers	9	.0001**	.0001	.0002	.0001
Between Periods	2	.0004	.0035**	.0001	.0000
Wraps X Periods	6	.0002	.0003	.0004	.0001
Lockers X Periods	6	.0010	.0027**	.0009*	.0004
Error	18	.0007	.0002	.0003	.0002

** Significant at the 1% level
* Significant at the 5% level

Table 12 shows the analysis of variance of the individual percentage weight losses and substantiates the observations made from Tables 10 and 11. It is therefore apparent that wrapping materials do affect weight losses of meat cuts during freezing and storage. The highly significant difference between wraps is probably due to the unusually large losses in weight of the wax paper wrapped cuts.

Drip and Cooking Losses

Drip losses refers to loss in weight of the meat cuts which occurred during the period after removal from the freezing unit and immediately before cooking. These losses as effected by wrapping materials are expressed as mean percentage values and shown in Table 13. The effects of freezing units on drip losses are similarly presented in Table 14.

Table 13.

MEAN PERCENTAGE DRIP LOSSES AS EFFECTED BY WRAPPING MATERIALS

	Wrapping Materials				
Meat Cut	No Air Wrap	Wax Paper	Laminated Aluminum Foil	Laminated Wax Paper	All Materials
Roasts	1.04*	0.31	1.35	1.79	1.12
Round Steak	5.60	1.85	5.00	3.94	4.10
Loin Steak	1.66	0.68	1.90	0.83	1.27
Ground Beef	+0.40	+0.53	+0.50	+0.66	+0.52
All Cuts	1.98	0.58	1.94	1.48	

* Expressed as per cent weight loss of all cuts.

The data in the above and following table show an unusual condition existing in the ground beef which gained weight regardless of wrapping material or freezing unit. It appears that factors other than wrapping materials and freezing units were affecting this particular type of meat. The drip losses were only slightly affected by wrapping materials or freezing units. The wax paper cuts seemed to have a slightly smaller

percentage weight loss and this may have been due to larger losses during storage.

Table 14.

MEAN PERCENTAGE DRIP LOSSES AS EFFECTED BY FREEZING UNITS

	Freezing Units				
Meat Cut	Locker Plant	Hot Point	Gibson	American	All Freezers
Roasts	0.77*	1.13	1.30	1.30	1.12
Round Steak	5.20	2.97	5.48	2.75	4.10
Loin Steak	1.45	0.97	1.82	0.83	1.27
Ground Beef	+0.50	+0.63	+0.52	+0.44	+0.52
All Cuts	1.73	1.11	2.02	1.11	

* Expressed as per cent weight loss of all cuts

Analytical data pertaining to drip losses of the various cuts of meat are presented in Table 15. The only highly significant differences associated with wraps and lockers were with the round steak cuts.

Table 15.

MEAN SQUARES OF VARIANCE OF PERCENTAGE WEIGHT LOSS ON THAWING

		Meat Cut			
Source of Variance	d/f	Roasts	Round Steak	Loin Steak	Ground Beef
Total	47				
Between Wraps	3	.00030	.00320**	.00043	.000000
Between Lockers	3	.00010	.00250**	.00027	.000000
Wraps X Lockers	9	.00008	.00023	.00013	.000011
Between Periods	2	.00140**	.00205**	.00275**	.000350**
Wraps X Periods	6	.00015	.00017	.00012	.000017*
Lockers X Periods	6	.00015	.00052*	.00017	.000017*
Error	18	.00006	.00017	.00020	.000006

** Significant at the 1% level
* Significant at the 5% level

The effects of wrapping materials on weight losses of the various cuts during cooking are presented in Table 16. These tabulations are mean percentage values of the losses occurring during the period from thawing to immediately after cooking.

Table 16.

MEAN WEIGHT LOSS DURING COOKING AS EFFECTED BY WRAPPING MATERIALS

	Wrapping Material				
Meat Cut	No Air Wrap	Wax Paper	Laminated Aluminum Foil	Laminated Wax Paper	All Materials
Roasts	21.36*	22.80	26.30	28.03	24.62
Round Steak	28.73	29.12	31.91	30.22	30.00
Loin Steak	23.82	27.12	27.51	23.58	25.51
Ground Beef	27.13	26.83	28.07	29.13	27.79
All Cuts	25.26	26.47	28.45	27.74	

* Expressed as per cent of original weight of all cuts

Observation of the data in Table 16 shows that the meat cuts frozen in the "No Air Wrap" material had the smallest mean percentage weight loss on cooking of all cuts except the ground beef, which had a cooking loss of three-tenths of a per cent less. In comparing the effects of the three paper materials studied, the wax paper shows the smallest percentage weight loss in most cases. This is probably due to the large losses in weight during freezing and storage of the cuts wrapped in this paper. Further observation of the above table shows that only slight differences exist in cooking losses due to the effects of the various wrapping materials. It is interesting to note, however, that large differences in means between the various cuts do exist. In all wrapping materials studied, the beef roasts had the smallest mean percentage weight loss. It may also be noted that the round steak had the greatest mean percentage weight loss. Due to the characteristic lean-fat ratio of this type of cut, it would indicate that

the greatest loss of weight during cooking comes from losses other than fat losses.

Table 17.

MEAN WEIGHT LOSS DURING COOKING AS EFFECTED BY FREEZING UNITS

	Freezing Unit				
Meat Cut	Locker Plant	Hot Point	Gibson	American	All Freezers
Roasts	23.62*	24.59	23.68	26.59	24.62
Round Steak	31.05	30.40	30.80	27.73	30.00
Loin Steak	31.12	24.43	24.43	22.06	25.51
Ground Beef	29.09	28.25	25.85	28.00	27.80
All Cuts	28.72	26.92	26.19	26.10	

* Expressed as per cent of original weight of all cuts.

Cooking losses as effected by freezing units are shown in Table 17. The statistical analysis of the cooking losses are presented in Table 18.

Table 18.

MEAN SQUARES OF VARIANCE OF PERCENTAGE WEIGHT LOSSES DURING COOKING

		Meat Cut			
Source of Variance	d/f	Roasts	Round Steak	Loin Steak	Ground Beef
Total	47				
Between Wraps	3	0.0114	0.0024	0.0052	0.0013
Between Lockers	3	0.0023	0.0028	0.0183**	0.0023
Wraps X Lockers	9	0.0031	0.0014**	0.0015	0.0011*
Between Periods	2	0.0041	0.0179	0.0648**	0.0600**
Wraps X Periods	6	0.0010*	0.0017*	0.0013	0.0010*
Lockers X Periods	6	0.0041	0.0007**	0.0040*	0.0008*
Error	18	0.0040	0.0073	0.0015	0.0013

** Significant at the 1% level
* Significant at the 5% level

It appears that wrapping materials have little if any effect on cooking losses of the meat cuts studied. Also the loin steak was the only cut of meat that showed any difference in cooking losses as the result of the freezing units. The means shown in Table 17 indicate that the locker plant is the freezing unit responsible for this difference.

Total Weight Losses

The effects of wrapping materials and freezing units on storage, drip and cooking losses have been presented. It was also desirable to determine the total percentage weight losses so that an over-all efficiency rating might be given to the various materials and freezing units studied.

Data showing total percentage weight losses of the various cuts as effected by wrapping materials are presented in Table 19.

Table 19.

MEAN TOTAL WEIGHT LOSSES AS EFFECTED BY WRAPPING MATERIALS

	Wrapping Material				
Meat Cut	No Air Wrap	Wax Paper	Laminated Aluminum Foil	Laminated Wax Paper	All Wraps
Roasts	23.82*	28.21	28.00	30.88	27.72
Round Steak	37.30	37.90	38.24	36.82	37.56
Loin Steak	28.11	34.05	30.28	26.04	29.62
Ground Beef	28.90	31.24	28.06	29.70	29.48
All Cuts	29.53	32.85	31.14	30.86	

* Expressed as per cent weight loss of all cuts.

Observation of the above table shows that differences in wrapping material means were present in only two cuts. The beef roasts had a range of 23.82 to 30.88 per cent as compared to a range of 26.04 to 34.05

per cent for the loin steaks. These differences in means are exceptionally large when compared to the ground beef, the next in line for means variation, which had a range of 28.06 to 31.24 per cent. Further observation of the above table shows that the means of laminated aluminum foil are quite similar to the means for all wrapping materials. It may also be noted that the greatest variation in total weight losses occurred in the "No Air Wrap", which had a range from 23.82 to 37.30 per cent for all cuts. This constitutes a difference of 14.52 per cent as compared to the next largest difference of 10.78 per cent for the laminated wax paper.

Mean total weight losses of the meat cuts as effected by freezer units are presented in Table 20.

Table 20.

MEAN TOTAL WEIGHT LOSSES AS EFFECTED BY FREEZING UNITS

	Freezing Unit				
Meat Cut	Locker Plant	Hot Point	Gibson	American	All Freezers
Roasts	25.84*	27.67	27.12	30.28	27.72
Round Steak	38.19	37.42	39.39	35.26	37.56
Loin Steak	34.79	28.88	29.08	25.73	29.62
Ground Beef	30.23	29.61	28.04	30.02	29.48
All Cuts	32.26	30.90	30.91	30.32	

* Expressed as per cent weight loss of all cuts.

Observation of this table shows all means to be very similar except in the case of the loin steak. This cut shows a mean difference of 9.06 per cent in comparison to the mean differences of the other cuts ranging from 2.19 to 4.44 per cent. It is interesting to note that the loin steak frozen in the locker plant had the largest mean total weight loss.

Table 21 shows the results of the analysis of variance of total percentage weight losses of all cuts.

Table 21.

MEAN SQUARES OF VARIANCE OF TOTAL PERCENTAGE WEIGHT LOSSES

		Meat Cut			
Source of Variance	d/f	Roasts	Round Steak	Loin Steak	Ground Beef
Total	47				
Between Wraps	3	.0100	.0005	.0141*	.0022
Between Lockers	3	.0041	.0036	.0171**	.0012
Wraps X Lockers	9	.0035	.0016	.0021	.0012
Between Periods	2	.0005	.0384**	.0417**	.0494**
Wraps X Periods	6	.0029	.0025	.0014	.0012
Lockers X Periods	6	.0095	.0014	.0077**	.0010
Error	18	.0048	.0018	.0016	.0005

** Significant at the 1% level
* Significant at the 5% level

Loin steak is the only cut of meat showing significant differences between wrapping materials and freezing units. It appears likely that the significant difference between wraps for this cut is due to the large mean total weight loss for wax paper as shown in Table 19. Also the means shown in Table 20 indicate that the locker plant is the freezing unit responsible for the highly significant difference between lockers.

DISCUSSION

Comparative Effects of Wrapping Materials

The wrapping materials tested in this study definitely effect freezing rate and length of freezing zone. They also had a definite effect on weight losses of the meat cuts during freezing and storage. The effect they have on drip losses appears to depend largely on the weight losses during freezing and storage. This is demonstrated by the wax paper wrapped cuts which showed the greatest weight loss during freezing and storage and the smallest weight losses from drip. Weight losses of the various cuts during cooking were not affected by wrapping materials.

Total weight losses of the meat cuts due to freezing and storage, drip and cooking were not greatly affected by the various wraps studied. These three factors, however, are not the only ones to be considered when the wraps are compared. Color of frozen, thawed, and cooked meat, palatability, juiciness, and aroma must be considered when overall comparisons and desirability ratings are made.

Laminated Aluminum Foil: This wrapping paper differed only slightly from the other paper materials studied in its effect on freezing zone and rate.

The protection afforded by this wrapping material was the most outstanding factor in its favor. It ranked first in comparison with the other wrapping materials studied in preventing loss of moisture during freezing and storage. The surfaces of the meat cuts were glazed and had an excellent natural beef color when the paper was removed. Only small amounts of cavity ice developed in the small air pockets around the meat

and this condition existed only in the most irregularly shaped packages. There was no evidence of dehydration after a storage period of ten months duration. This paper also conformed well to the shape of the meat cuts, which factor is of great importance in controlling and preventing freezer burn.

Organoleptic tests of the cooked meat revealed that it was more juicy and had a more desirable meat flavor than the meat wrapped in the other materials. Other factors in favor of this paper were its easy removal from the frozen meat and its retention of pliability at low temperatures. It was tough and resistant to tears and punctures and did not impart a flavor to the meat. This paper was rated the best of all the wrapping materials used in this study when all factors concerning desirability were considered.

"No Air Wrap": This type of wrapping material was the most efficient when considered from the standpoint of freezing rate and length of time required in passing through the freezing zone. It rated second in its ability to preserve natural color and quality of meat during the storage period. Some packages, however, did not withstand the intermittent handling required when rearranging the packages in the freezer units. This was especially noticeable on such cuts as round and loin steaks which have relatively large areas of smooth and flat surface. It was much more satisfactory when used on cuts such as ground beef which are irregular in shape and have a surface which lends itself to much more secure adherence of the wax material. This wrapping material ranked third in percentage weight losses during freezing and storage period. This probably was the result of the losses occurring during the freezing

process before the cut was covered with the wax material. There were practically no differences in percentage weight losses between "No Air Wrap" and the laminated foil and laminated wax papers. The "No Air Wrap" had the largest percentage weight losses during the cooking period of all wrapping materials studied.

Several disadvantages of this wrapping material were noted during the course of the experiment. The most objectionable of these was that it chipped and cracked if handled excessively. When this condition existed, the exposed areas were very susceptible to dehydration and cavity ice developed in the air pockets formed between the wax covering and the meat. Another disadvantage of this wrapping material is the difficulty which is encountered when packaging thin cuts of meat such as steaks and chops. Most packages of the latter type are irregular and non-uniform in shape and require extra space in the storage compartment.

The "No Air Wrap" was rated second in order of preference when all factors such as freezing rate, preservation of color and quality and drip and cooking losses were considered. It was excelled only by the laminated foil wrapping material.

Laminated Wax Paper: This wrapping material ranked third in overall desirability of the four wrapping materials tested. When considered from the standpoint of freezing zone and rate, it was very similar to the other materials used. It afforded an average amount of protection to the meat but it did not approach the same degree of desirability as the laminated aluminum foil or the "No Air Wrap". Weight losses during freezing and storage of cuts frozen in this paper were very similar to

the weight losses of cuts frozen in the "No Air Wrap". The meat was slightly freezer burned, however, after a ten months storage period. The meat wrapped in this material had larger amounts of cavity ice between the wrapper and the meat than any cuts wrapped in the other wrapping materials studied. This factor was a result of the paper not conforming to the shape of the meat cut. Little difficulty was encountered in removing the laminated wax paper from the frozen meat and the surface of the meat had a fair color.

Weight losses during thawing and cooking as a result of this paper were very similar to those of similar cuts wrapped in the other wrapping materials tested. Organoleptic tests showed that the quality of the cooked meat which was wrapped in this material was not as desirable as that of similar cuts wrapped in the "No Air Wrap" or laminated aluminum foil. It was, however, highly superior in all respects to that of the meats wrapped in the waxed locker paper.

Wax Paper: Only slight differences were noted between this wrapping material and all other paper materials studied when compared on freezing rates and length of freezing zone. From the standpoint of protection afforded by this wrapping material during the freezing and storage period, it was rated as the least desirable of all wrapping materials used in this study. It had the largest percentage weight loss during freezing and storage of all materials studied. In this respect the mean weight loss for all cuts wrapped in wax paper was 5.66 per cent as compared with the "No Air Wrap" having the next highest mean weight loss for all cuts of 2.29 per cent. This is an increase of 3.37 per cent and was highly significant when analyzed statistically. It also

showed the least ability to protect meat from dehydration even in storage periods as short as four months duration. It was also noted that the meat cuts which were wrapped in wax paper did not have as large percentage weight losses during the thawing period as similar cuts frozen in the other wrapping materials. This fact was attributed to the high degree of dehydration which occurred during freezing and storage. There were only slight differences in cooking losses between meat cuts wrapped in this material and similar cuts wrapped in the other materials used in this study.

The excessive dehydration which was present in all cuts of meat wrapped in this material was greatly reflected in the quality of the cooked meats. These products were somewhat dry and tasteless but did not exhibit any noticeable amount of rancidity after a ten months storage period.

This wrapping material had the least ability to preserve meat in a satisfactory manner during freezing and storage of all wrapping materials studied. It must be remembered that the drug-store style wrap was used in this study, which allows for only one thickness of paper covering the meat. This factor is undoubtedly one reason why the wax paper was so inefficient.

General Discussion

The effect of various wrapping materials on freezing rate, quality and cooking losses of different types of meat cuts was the principal objective of this investigation. Additional information in regard to drip loss and length of freezing zone was also of primary importance. The study was so designed that all information obtained would be of

value to persons freezing and storing meat in either commercial or home freezer units. The freezing unit has been the secondary component in this study and they were found to have certain effects on meat frozen in them.

It was found that all home freezers froze the meat cuts at a faster rate than the locker plant. The average smaller size of the meat cuts frozen in the home units may be the contributing factor of this faster freezing rate. A smaller freezing load in relation to freezing compartment temperature was probably the main contributing factor to the faster freezing rate in the home freezer units. It was noted in the course of the experiment that after the meat was placed in the home freezing unit the air temperature in the freezing compartments ranged from 0° F. at the beginning to a - 20° F. at the end of the freezing period. The locker plant with its characteristically larger more heavily loaded freezing compartment usually was maintained at a - 10° F. The freezing compartment of the American home unit would go as low as - 35° F. during a twenty-four hour period. In comparison to size of unit and freezing load, the Gibson home unit had the fastest freezing rate of the home units studied. This is probably due to the freezing plate shelf design which allows more of the flat surface of the meat package to come in contact with the freezing unit.

Weight losses of the various meat cuts during freezing and storage, thawing and cooking showed significant differences between freezing units in one or two cases. From the limited number of freezing units used, no definite conclusions can be made, but from the data presented it appears that they do not effect weight losses. The data does show, however, that

the length of storage period has some effect on these weight losses. This was probably due to the two home freezers which were out of order for a period of seventy-two hours because of a power failure. The cuts in these two freezers became thawed and were then refrozen. This thawing did not affect the flavor of the cooked meat when organoleptic tests were made.

The results of this study show that much work remains to be done in this line of investigation. It would be desirable to test more wrapping materials and use replications of home units in future studies. This would be necessary if true differences between freezing units are to be found.

SUMMARY AND CONCLUSIONS

Four wrapping materials - "No Air Wrap", wax paper, laminated aluminum foil and laminated wax paper - which are available for meat freezing were tested. Beef cuts - roasts, round steak, loin steak and ground beef - were wrapped in the various materials and frozen in three home freezer units - Hot Point, Gibson and American and a commercial locker plant. Tests included freezing zone and rate, and weight losses due to freezing and storage, drip and cooking. All tests were analyzed statistically.

1. Highly significant differences were found between wrapping materials as they affect freezing zone and rate. This was due to the shorter freezing zone and faster freezing rate for the "No Air Wrap". The other paper material had only slight effects on these two factors.
2. Highly significant differences were found between wrapping materials as they affected moisture losses during freezing and storage. Wax paper was very inferior and the laminated aluminum foil was highly superior in prevention of moisture losses. The "No Air Wrap" and laminated wax paper were about equal in this respect.
3. The effect of wrapping materials on drip was dependent on weight losses during freezing and storage. Cooking losses were not greatly affected by wrapping materials.
4. Total weight losses were not affected by wrapping materials except in the case of loin steak.

5. Home freezer units have a shorter freezing zone and faster freezing rate than the locker plant.
6. Weight losses were not affected by freezing units in most cases. Those differences which were found were not statistically significant as not enough freezers were tested.

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